

## Part 4. Probability Estimates on Different Size Scales For the Features Required by Advanced Life

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For human life (or its functional equivalent) to possibly establish a globally distributed high-technology civilization on some kind of astronomical body, many characteristics of its environment — from large-scale to small, galaxy cluster to proximate ecosystems — must take on specific values. These characteristics are listed below on eight specific size scales, large to small, along with estimates from a naturalistic perspective (assumption that no supernatural Being is responsible for fixing the value of any of the characteristics) of the probabilities that the values of these characteristics will fall within the required ranges. Estimates of the dependency factors among the different characteristics are accounted for at the end of the list as well as estimates of the longevity factors (the requirements that the values of the characteristics would remain within the ranges required for humans manifesting a globally distributed high-technology civilization for the duration of that human existence). Using these estimates and the data from the list, a calculation is performed for the probability that the observable universe would, from a naturalistic perspective, contain at least one galaxy cluster capable of supporting such technologically advanced humans.

Citations to the scientific literature in which the fine-tuning of all the characteristics herein listed are analyzed may be found at the end of the lists.

### A. Galaxy Cluster

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<b>Parameter</b>	<b>Probability that feature will fall in the required range for advanced physical life</b>
relative abundances of different exotic mass particles	.01
density of quasars in the local volume of the universe during early cosmic history	.1
density of giant galaxies in the local volume of the universe during early cosmic history	.03
variability of local dwarf galaxy absorption rate	.1
timing of hypernovae eruptions	.2
number of hypernovae eruptions	.1
masses of stars that become hypernovae	.1
flux of cosmic ray protons	.1
variability of cosmic ray proton flux	.1
rate of in-spiraling gas into galaxy's central black hole during life epoch	.02

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distance from nearest giant galaxy	.4
distance from nearest Seyfert galaxy	.9
galaxy cluster formation rate	.1
tidal heating from neighboring galaxies	.5
tidal heating from dark galactic and galaxy cluster halos	.5
density of dwarf galaxies in vicinity of home galaxy	.02
number of giant galaxies in galaxy cluster	.1
number of large galaxies in galaxy cluster	.1
number of dwarf galaxies in galaxy cluster	.1
average quantity of gas infused into the universe's first star clusters that reside in the vicinity of the potential life support galaxy	.1
level of supersonic turbulence in the vicinity of the potential life support galaxy during the infancy of the universe	.05
number and sizes of intergalactic hydrogen gas clouds in galaxy's vicinity	.05
average longevity of intergalactic hydrogen gas clouds in galaxy's vicinity	.1
number density of the first metal-free stars to form in the vicinity of the future life support galaxy	.02
epoch at which the first metal-free stars form in the vicinity of of the future potential life support galaxy	.1
number densities of metal-poor and extremely metal-poor galaxies in vicinity of potential life support galaxy	.1
heavy element abundance in the intracluster medium for the early universe in the vicinity of the potential life support galaxy	.1
rate of infall of intergalactic gas into emerging and growing galaxies during first five billion years of cosmic history in the vicinity of the potential life support galaxy	.1
pressure of the intra-galaxy-cluster medium in the vicinity of the potential life support galaxy	.1
sizes of largest cosmic structures in the local region of the universe	.01
quantity of dust formed in the ejecta of Population III supernovae in vicinity of future life support galaxy	.1
chemical composition of dust ejected by Population III stars in vicinity of future life support galaxy	.3
epoch when the merging of galaxies peaks in the vicinity of potential life support galaxy	.03
density of extragalactic intruder stars in solar neighborhood	.2
average rate of increase in galaxy sizes in the local region of the universe	.05
change in average rate of increase in galaxy sizes throughout cosmic history in the local region of the universe	.1
timing of star formation peak for the local part of the universe	.2
dwarf galaxy merger rate with home galaxy	.03
epoch at which metal-free (pop III) stars cease forming in vicinity of potential life support galaxy	.1
average mass of metal-free (pop III) stars in vicinity of potential life support galaxy	.1
epoch in cosmic history at which number density of gamma	

ray burst events peak in the local volume of the universe	.3
number density of clumpuscules (dense cold clouds of molecular hydrogen gas) in the vicinity of the galaxy	.1
average mass of clumpuscules in the vicinity of the galaxy	.1
location of clumpuscules in the vicinity of the galaxy	.01
density of ultra-dwarf galaxies (or supermassive globular clusters) in vicinity of the galaxy	.05
galaxy cluster size	.01
galaxy cluster density	.03
galaxy cluster location	.02
number of medium- or large-sized galaxies merging with the galaxy since the formation and stabilization of its thick galactic disk	.2
intensity of superwinds generated by primordial supermassive black holes	.03
number of superwind events generated by primordial supermassive black holes	.03
density of galaxies in the local volume around life-support galaxy	.1
average galaxy mass in the local volume around life-support galaxy	.1
ratio of baryons in galaxy clusters to baryons in between galaxy clusters within the Local Volume of the universe	.1
ratio of baryons in galaxies to baryons in between galaxies in the Local Volume of the universe	.1
infall velocity of galaxy toward center of nearest grouping of galaxies	.05
infall velocity of galaxy toward center of nearest supercluster of galaxies	.1
distance that primordial supernovae dispersed elements heavier than helium	.03
percentage of galaxies containing stars with planets in stable orbits	.1
percentage of stars in galaxy with planets in stable orbits	.02
quantity of molecular hydrogen formed by the supernova eruptions of population III stars (the first born stars) in the vicinity of the potential life-support galaxy	.01
percent of baryons processed by the first stars (population III stars) in the vicinity of and inside the primordial Milky Way Galaxy	.04
number of large galaxy collisions with the Milky Way Galaxy during the past ten billion years	.03
number of large galaxy collisions in the near vicinity of the Milky Way Galaxy during the past ten billion years	.05
degree of suppression of dwarf galaxy formation by cosmic reionization in the local volume of the universe	.02
number of ultracompact dwarf galaxies in the vicinity of the potential life support galaxy during that galaxy's youth	.1
number of starless hydrogen gas clouds in the near vicinity of the potential life support galaxy	.05

average mass of starless hydrogen gas clouds in the near vicinity of the potential life support galaxy	.05
number density of dark matter minihalos in the primordial Local Group	.01
shape of the galaxy cluster	.5
shape of the galaxy supercluster	.5
timing for the formation of the first stars in the vicinity of the Local Group of galaxies	.05
timing for the complete reionization of the local intergalactic medium	.05
average mass of accreted intergalactic clouds in the vicinity of the emerging solar system nebula	.3
number density of accreted intergalactic clouds in the vicinity of the solar system during its life history	.1
average mass of accreted intergalactic clouds in the vicinity of the solar system during its life history	.1
density of matter in and about the environs of the Local Group of galaxies	.1
density of baryons in the Local Volume of the universe	.05
density of baryons in the Local Group of galaxies	.05
ratio of baryons in galaxies to baryons in between galaxies in the Local Group of galaxies	.1
number density of intracluster clouds in and around the Local Group of galaxies	.1
average mass of intracluster clouds in and around the Local Group of galaxies	.1
temperature of the hot intracluster medium for the Local Group of galaxies	.05
richness or density of galaxies in the supercluster of galaxies	.1
density of dwarf dark matter halos in the vicinity of the Milky Way Galaxy	.01
metallicity enrichment by dwarf galaxies of the intergalactic medium in the vicinity of the potential life support galaxy	.1
average star formation rate throughout cosmic history for dwarf galaxies that are in the vicinity of the potential life support galaxy	.02
quantity of heavy elements infused into the intergalactic medium by dwarf galaxies in the vicinity of the potential life support galaxy during the first two billion years of cosmic history	.03
quantity of heavy elements infused into the intergalactic medium by the superwinds of large galaxies in the vicinity of the potential life support galaxy during the first two billion years of cosmic history	.03
average size of cosmic voids in the vicinity of the potential life support galaxy	.5
number of cosmic voids per unit of cosmic space in the vicinity of the potential life support galaxy	.5
number of galaxies per unit of dark matter halo virial mass in the vicinity of the potential life support galaxy	.1
ratio of the number density of dark matter subhalos to the number density of dark matter halos in the vicinity of the potential	

life support galaxy	.1
quantity of diffuse, large-grained intergalactic dust in the vicinity of the potential life support galaxy	.1
ratio of baryonic matter to exotic matter in dwarf galaxies in the vicinity of the potential life support galaxy	.1
ratio of baryons in the intergalactic medium relative to baryons in the circumgalactic medium for the potential life support galaxy	.1
intergalactic photon density in the vicinity of the potential life support galaxy	.4
quantity of baryons in the warm-hot intergalactic medium in the vicinity of the potential life support galaxy	.2
distance of the Magellanic Clouds from the Milky Way Galaxy	.5

Probability for occurrence of all 99 parameters  $\approx 10^{-110}$   
 dependency factors estimate  $\approx 10^{54}$   
 longevity requirements estimate  $\approx 10^{-6}$

Probability for occurrence of all 99 parameters  $\approx 10^{-62}$   
 Maximum possible number of galaxy clusters in observable universe  $\approx 10^9$

Thus, less than 1 chance in  $10^{53}$  exists that even one such galaxy cluster would occur anywhere in the universe without invoking divine miracles.

## B. GALAXY

Parameter	Probability that feature will fall in the required range for advanced physical life
galaxy size	.01
galaxy type	.1
galaxy mass distribution	.02
size of galactic central bulge	.05
galaxy location	.01
variability of local dwarf galaxy absorption rate	.1
quantity of galactic dust	.1
giant star density in galaxy	.1
ratio of inner dark halo mass to stellar mass for galaxy	.1
timing of hypernovae eruptions	.2
number of hypernovae eruptions	.1
masses of stars that become hypernovae	.1
flux of cosmic ray protons	.1
variability of cosmic ray proton flux	.1
number & timing of solar system encounters	
with interstellar gas clouds and cloudlets	.01
galactic tidal forces on planetary system	.1
density of interstellar and interplanetary dust particles in	
vicinity of life-support planet	.1
silicate dust annealing by nebular shocks	.02
mass of the galaxy's central black hole	.01
date for the formation of the galaxy's central black hole	.05
timing of the growth of the galaxy's central black hole	.1
rate of in-spiraling gas into galaxy's central black hole during	
life epoch	.02
distance from nearest giant galaxy	.4
distance from nearest Seyfert galaxy	.9
quantity of magnetars (proto-neutron stars with very strong	
magnetic fields) produced during galaxy's history	.05
ratio of galaxy's dark halo mass to its baryonic mass	.2
ratio of galaxy's dark halo mass to its dark halo core mass	.2
tidal heating from neighboring galaxies	.5
tidal heating from dark galactic and galaxy cluster halos	.5
intensity and duration of galactic winds	.3
density of dwarf galaxies in vicinity of home galaxy	.02
in-spiral rate of stars into black holes within parent galaxy	.5
injection efficiency of shock wave material from nearby	
supernovae into collapsing molecular cloud that forms	
star and planetary system	.01
number of giant galaxies in galaxy cluster	.1
number of large galaxies in galaxy cluster	.1
number of dwarf galaxies in galaxy cluster	.1
distance of galaxy's corotation circle from center of galaxy	.03

rate of diffusion of heavy elements from galactic center out to the galaxy's corotation circle	.1
outward migration of star relative to galactic center	.2
average quantity of gas infused into the universe's first star clusters that reside in the vicinity of the potential life support galaxy	.1
level of supersonic turbulence in the vicinity of the potential life support galaxy during the infancy of the universe	.05
number and sizes of intergalactic hydrogen gas clouds in galaxy's vicinity	.05
average longevity of intergalactic hydrogen gas clouds in galaxy's vicinity	.1
number density of the first metal-free stars to form in the vicinity of the future life support galaxy	.02
epoch at which the first metal-free stars form in the vicinity of the future potential life support galaxy	.1
number densities of metal-poor and extremely metal-poor galaxies in vicinity of potential life support galaxy	.1
rate of growth of central spheroid for the galaxy	.01
amount of gas infalling into the central core of the galaxy	.05
level of cooling of gas infalling into the central core of the galaxy	.1
heavy element abundance in the intracluster medium for the early universe in the vicinity of the potential life support galaxy	.1
rate of infall of intergalactic gas into emerging and growing galaxies during first five billion years of cosmic history in the vicinity of the potential life support galaxy	.1
pressure of the intra-galaxy-cluster medium in the vicinity of the potential life support galaxy	.1
sizes of largest cosmic structures in the local region of the universe	.01
level of spiral substructure in spiral galaxy	.1
supernova eruption rate when galaxy is young	.2
range of rotation rates for stars in the galaxy that are on the verge of becoming supernovae	.2
quantity of dust formed in the ejecta of Population III supernovae in vicinity of future life support galaxy	.1
chemical composition of dust ejected by Population III stars in vicinity of future life support galaxy	.3
epoch when the merging of galaxies peaks in the vicinity of potential life support galaxy	.03
density of extragalactic intruder stars in solar neighborhood	.2
average rate of increase in galaxy sizes in the local region of the universe	.05
change in average rate of increase in galaxy sizes throughout cosmic history in the local region of the universe	.1
quantity and proximity of gamma-ray burst events relative to emerging solar nebula	.01
proximity of superbubbles to planetary system during life epoch of life-support planet	.02
quantity and proximity of galactic gamma-ray burst events	

relative to time window for intelligent life	.1
dwarf galaxy merger rate with home galaxy	.03
density of black holes, neutron stars, and plerionic supernova remnants in the galaxy	.1
epoch at which metal-free (pop III) stars cease forming in vicinity of potential life support galaxy	.1
average mass of metal-free (pop III) stars in vicinity of potential life support galaxy	.1
epoch in cosmic history at which number density of gamma ray burst events peak in the local volume of the universe	.3
density of molecular hydrogen in the galaxy	.1
number density of clumpuscles (dense cold clouds of molecular hydrogen gas) in the vicinity of the galaxy	.1
average mass of clumpuscles in the vicinity of the galaxy	.1
location of clumpuscles in the vicinity of the galaxy	.01
diameter of ordinary dark matter halo surrounding the galaxy	.1
mass of ordinary dark matter halo surrounding the galaxy	.1
diameter of exotic dark matter halo surrounding the galaxy	.1
mass of exotic dark matter halo surrounding the galaxy	.1
density of ultra-dwarf galaxies (or supermassive globular clusters) in vicinity of the galaxy	.05
formation rate of molecular hydrogen on dust grain surfaces when the galaxy is young	.1
number of medium- or large-sized galaxies merging with the galaxy since the formation and stabilization of its thick galactic disk	.2
amount of buildup of heavy elements in the galaxy	.03
timescale for the buildup of heavy elements in the galaxy	.02
intensity of superwinds generated by primordial supermassive black holes	.03
number of superwind events generated by primordial supermassive black holes	.03
galaxy mass	.02
density of galaxies in the local volume around life-support galaxy	.1
average galaxy mass in the local volume around life-support galaxy	.1
average mass of cold dark gas-dust clouds in the galaxy	.1
number density of cold dark gas-dust clouds in the galaxy	.1
time in galactic history when cold dark gas-dust clouds form	.1
date of star formation shutdown in the galaxy	.02
degree of central concentration of light-emitting ordinary matter for the life-support galaxy	.05
degree of flatness for the light-emitting ordinary matter for the life-support galaxy	.05
degree of sphericity for the distribution of ordinary dark matter for the life-support galaxy	.1

degree of sphericity for the distribution of exotic dark matter for the life-support galaxy	.1
level of carbon abundance in the galaxy	.05
gradient of carbon abundance with respect to distance from galactic center	.05
level of oxygen abundance in the galaxy	.05
gradient of oxygen abundance with respect to distance from galactic center	.05
level of nitrogen abundance in the galaxy	.1
gradient of nitrogen abundance with respect to distance from galactic center	.1
infall velocity of galaxy toward center of nearest grouping of galaxies	.05
infall velocity of galaxy toward center of nearest supercluster of galaxies	.1
distance that primordial supernovae dispersed elements heavier than helium in the vicinity of the galaxy	.03
number of gamma ray burst events in the galaxy during life history on the life support planet	.1
percentage of stars in galaxy with planets in stable orbits	.02
quantity of molecular hydrogen formed by the supernova eruptions of population III stars (the first born stars) in the vicinity of the potential life-support galaxy	.01
rate of destruction and dispersal of dust as a result of supernova eruptions in the potential life-support galaxy	.1
percent of baryons processed by the first stars (population III stars) in the vicinity of and inside the primordial Milky Way Galaxy	.04
solar system's orbital radius about the center of the Milky Way Galaxy	.01
number of large galaxy collisions with the Milky Way Galaxy during the past ten billion years	.03
number of large galaxy collisions in the near vicinity of the Milky Way Galaxy during the past ten billion years	.05
frequency of core collapse supernovae	.1
shape of the Milky Way Galaxy's ordinary dark matter halo	.1
level of warping in the Milky Way Galaxy's spiral disk	.1
frequency of long-lasting gamma ray bursts	.1
proximity of long-lasting gamma ray bursts	.01
frequency of gamma ray burst events in the galaxy	.01
density of the galaxy	.01
degree of suppression of dwarf galaxy formation by cosmic reionization in the local volume of the universe	.02
rate of decrease of the thickness of the gas disk in the life-support galaxy	.1
oxygen abundance in the galactic bulge	.1
production of $H_3^+$ by the galaxy's population III (first generation) stars	.05
production of $H_3^+$ by the galaxy's population II	

(second generation) stars	.05
gas density of the local interstellar medium	.05
number of ultracompact dwarf galaxies in the vicinity of the potential life support galaxy during that galaxy's youth	.1
number of starless hydrogen gas clouds in the near vicinity of the potential life support galaxy	.05
average mass of starless hydrogen gas clouds in the near vicinity of the potential life support galaxy	.05
dust to gas ratio in and near the core of the potential life support galaxy during that galaxy's youth	.1
dust temperature in and near the core of the potential life support galaxy during that galaxy's youth	.1
gas temperature in and near the core of the potential life support galaxy during that galaxy's youth	.1
dust to gas ratio in the mid to outer parts of the potential life support galaxy during that galaxy's youth	.1
dust temperature in the mid to outer parts of the potential life support galaxy during that galaxy's youth	.1
gas temperature in the mid to outer parts of the potential life support galaxy during that galaxy's youth	.1
quantity of carbon monoxide in the potential life support galaxy early in its history	.1
quantity of carbon monoxide in the potential life support galaxy late in its history	.1
number density of dark matter minihalos in the primordial Local Group	.01
intensity or speed of high-velocity galactic outflows during the youth of the potential life support galaxy	.01
thickness of the thick disk for the potential life support galaxy	.03
rate at which the thick disk for the potential life support galaxy grows thinner	.1
epoch of peak production of type I supernovae in the potential life support galaxy	.1
average frequency of the different kinds of type I supernovae in the potential life support galaxy	.1
epoch of peak production of type II supernovae in the potential life support galaxy	.1
average frequency of the different kinds of type II supernovae in the potential life support galaxy	.1
virial radius of the exotic matter halo surrounding the potential life support galaxy	.02
mass of the corona surrounding the potential life support galaxy	.1
diameter of the corona surrounding the potential life support galaxy	.1
average strength of local gravitational instabilities in the potential life support galaxy	.03
level of magnetic turbulence in the galactic interstellar medium	.1
timing for the formation of the first stars in the vicinity of the Local Group of galaxies	.05
timing for the complete reionization of the local intergalactic medium	.05
number density of accreted intergalactic clouds in the vicinity	.05

of the solar system during its life history	.1
average mass of accreted intergalactic clouds in the vicinity of the solar system during its life history	.1
number of supernova remnants in the vicinity of the life-support planet	.05
variation in the number of supernova remnants in the vicinity of the life support planet	.2
supernova rate in the life support galaxy	.1
timing of the initiation of enrichment of the interstellar medium with s-process elements for the potential life-support galaxy	.1
density of matter in and about the environs of the Local Group of galaxies	.1
density of baryons in the Local Volume of the universe	.05
density of baryons in the Local Group of galaxies	.05
ratio of baryons in galaxies to baryons in between galaxies in the Local Group of galaxies	.1
epoch of peak star formation in the potential life support galaxy	.01
ratio of type I to type II supernovae in the potential life support galaxy	.02
ratio of polycyclic aromatic hydrocarbons to stars in the galaxy	.05
number density of intracluster clouds in and around the Local Group of galaxies	.1
average mass of intracluster clouds in and around the Local Group of galaxies	.1
metallicity of the galaxy's halo	.02
shape of the galactic dark matter halo	.1
temperature of the hot intracluster medium for the Local Group of galaxies	.05
number density of dark matter subhalos surrounding the galaxy	.1
average mass of the dark matter subhalos surrounding the galaxy	.1
formation times for the dark matter halo and subhaloes surrounding the galaxy	.01
rate of growth of the galactic bulge in the spiral galaxy	.03
strength of the ultraviolet background for the protogalaxy	.1
extent of the warp of the galactic disk	.1
infall velocity of matter into the dark matter halo of the potential life support galaxy	.05
level of magnetization of the spiral disk for the potential life support galaxy	.05
percentage of the Milky Way Galaxy's halo that is comprised of MACHOs	.2
metallicity of the galaxy's halo	.1
strength of the wind emanating from the galaxy's nuclear core	.05
variation in the strength of the wind emanating from the galaxy's nuclear core	.05
mass of the initial or primordial galaxy	.005
strength of the vertical magnetic field emanating from the galactic center	.1
date when half the stars in the galaxy would have already been formed	.02
density of dwarf dark matter halos in the vicinity of the Milky	

Way Galaxy	.01
metallicity enrichment by dwarf galaxies of the intergalactic medium in the vicinity of the potential life support galaxy	.1
average star formation rate throughout cosmic history for dwarf galaxies that are in the vicinity of the potential life support galaxy	.02
quantity of heavy elements infused into the intergalactic medium by dwarf galaxies in the vicinity of the potential life support galaxy during the first two billion years of cosmic history	.03
quantity of heavy elements infused into the intergalactic medium by the superwinds of large galaxies in the vicinity of the potential life support galaxy during the first two billion years of cosmic history	.03
average size of cosmic voids in the vicinity of the potential life support galaxy	.5
number of cosmic voids per unit of cosmic space in the vicinity of the potential life support galaxy	.5
number of galaxies per unit of dark matter halo virial mass in the vicinity of the potential life support galaxy	.1
ratio of the number density of dark matter subhalos to the number density of dark matter halos in the vicinity of the potential life support galaxy	.1
quantity of diffuse, large-grained intergalactic dust in the vicinity of the potential life support galaxy	.1
ratio of baryonic matter to exotic matter in dwarf galaxies in the vicinity of the potential life support galaxy	.1
ratio of baryons in the intergalactic medium relative to baryons in the circumgalactic medium for the potential life support galaxy	.1
intergalactic photon density in the vicinity of the potential life support galaxy	.4
quantity of baryons in the warm-hot intergalactic medium in the vicinity of the potential life support galaxy	.2
distance of the Magellanic Clouds from the Milky Way Galaxy	.5

Probability for occurrence of all 200 parameters  $\approx 3 \times 10^{-239}$   
dependency factors estimate  $\approx 10^{105}$   
longevity requirements estimate  $\approx 10^{-12}$

Probability for occurrence of all 200 parameters  $\approx 3 \times 10^{-146}$   
Maximum possible number galaxies in observable universe  $\approx 3 \times 10^{11}$

Thus, less than 1 chance in  $10^{135}$  exists that even one such galaxy would occur anywhere in the universe without invoking divine miracles.

## C. Star

Parameter	Probability that feature will fall in the required range for advanced physical life
star distance from closest spiral arm	.1
z-axis extremes of star's orbit	.02
proximity of solar nebula to a normal type I supernova eruption	.01
timing of solar nebula formation relative to a normal type I supernova eruption	.01
proximity of solar nebula to a type II supernova eruption	.01
timing of solar nebula formation relative to type II supernova eruption	.01
gas dispersal rate by companion stars, shock waves, and molecular cloud expansion in the Sun's birthing star cluster	.1
number of stars in birthing cluster	.01
star formation rate in parent star vicinity during history of that star	.1
variation in star formation rate in parent star vicinity during history of that star	.1
birth date of the star-planetary system	.01
number of stars in planetary system	.7
number and timing of close encounters by nearby stars	.01
proximity of close stellar encounters	.01
masses of close stellar encounters	.03
density of brown dwarfs in neighborhood of life support planet	.1
absorption rate of planets and planetismals by parent star	.1
star age	.0001
star metallicity	.01
star orbital eccentricity	.1
star mass	.001
star luminosity change relative to speciation types & rates	.0000001
star luminosity change relative to speciation dates	.0000001
star color	.1
star rotation rate	.3
rate of change in star rotation rate	.3
star magnetic field	.05
star magnetic field variability	.1
stellar wind strength	.05
stellar wind variability	.1
short period variation in parent star diameter	.1
star's carbon to oxygen ratio	.01
star's space velocity relative to Local Standard of Rest	.05
star's short term luminosity variability	.02
star's long term luminosity variability	.05
amplitude and duration of star spot cycle	.1

number & timing of solar system encounters	
with interstellar gas clouds and cloudlets	.01
polycyclic aromatic hydrocarbon abundance in solar nebula	.01
tidal force from sun	.1
amount of mass loss by star in its youth	.1
rate of mass loss of star in its youth	.3
rate of mass loss by star during its middle age	.1
variation in coverage of star's surface by faculae	.4
proximity of supernovae and hypernovae throughout history	
of planet and planetary system	.002
amount of photoevaporation during planetary formation	
from parent star and other nearby stars	.1
strength of magnetocentrifugally launched wind of parent	
star during its protostar era	.2
injection efficiency of shock wave material from nearby	
supernovae into collapsing molecular cloud that forms	
star and planetary system	.01
number and sizes of planets and planetesimals consumed by	
star	.3
outward migration of star relative to galactic center	.2
long and medium period variations in star's diameter	.1
level of spot production on star's surface	.1
variability of spot production on star's surface	.2
average circumstellar medium density for white dwarf red	
giant pairs in the vicinity of the potential life support	
planet's protoplanetary disk	.1
proximity of solar nebula to a type I supernova whose core	
underwent significant gravitational collapse before	
carbon deflagration	.01
timing of solar nebula formation relative to a nearby type I	
supernova whose core underwent significant gravitational	
collapse before carbon deflagration	.005
proximity of emerging solar nebula relative to a nearby type I	
supernova whose core underwent significant gravitational	
collapse before carbon deflagration	.005
density of extragalactic intruder stars in solar neighborhood	.2
density of dust-exporting stars in solar neighborhood	.2
proximity of solar nebula to asymptotic giant branch stars	.05
timing of solar nebula formation relative to its close approach	
to asymptotic giant branch stars	.05
quantity and proximity of gamma-ray burst events relative	
to emerging solar nebula	.01
proximity of superbubbles to planetary system during life	
epoch of life-support planet	.02
proximity of strong ultraviolet emitting stars to planetary	
system during life epoch of life-support planet	.02
quantity and proximity of galactic gamma-ray burst events	
relative to time window for intelligent life	.1
infall of buckminsterfullerenes from interplanetary and	
interstellar space upon surface of planet	.3
flux of extrasolar dust into atmosphere	.5

rate at which protoplanetary disk photoevaporates	.05
type, degree, and duration of interaction between the protoplanet and the circumstellar disk	.01
solar nebula exposure to stellar winds from expanding asymptotic giant branch stars	.05
long term water loss from planet due to photodissociation	.01
average magnetic field strength in star's atmosphere	.1
anisotropy level of radiation field in star's atmosphere	.1
pebble density in solar nebula's protoplanetary disk	.005
rate at which solar nebula ran away from its birth cluster	.01
diffuse x-ray emission from nearest spiral arms	.05
intensity of far ultraviolet radiation from nearby stars when the circumsolar disk was condensing into planets	.001
phosphorus abundance in solar nebula	.03
rate at which the triple-alpha process (combining of three helium nuclei to make one carbon nucleus) runs inside the nuclear furnaces of stars	.002
proximity of gamma ray burst events to the life-support planet during the planet's life history	.1
photo erosion by nearby giant stars during planetary formation phase	.005
surface density of the protoplanetary disk	.01
ratio of mass in the form of debris relative to mass in the form of planetesimals for the protoplanetary disk	.1
mass of the Sun's primordial gas-dust disk	.03
longevity of the Sun's primordial gas-dust disk	.05
timing of solar system's last crossing of a spiral arm	.02
solar system's orbital radius about the center of the Milky Way Galaxy	.01
proximity of emerging solar system nebula to red giant stars	.05
number of red giant stars in close proximity to emerging solar system nebula	.1
masses of red giant stars in close proximity to emerging solar system nebula	.1
proximity of emerging solar system nebula to fluorine-ejecting planetary nebulae	.05
number of fluorine-ejecting planetary nebulae in close proximity to emerging solar system nebula	.1
rate at which the sun loses masses during its first 1.0 to 1.5 billion years	.1
eccentricity of sun's orbit about the galactic center	.05
inclination of sun's orbit about the galactic center	.05
timing of potential life-support planet's birth relative to spiral substructure formation	.1
luminosity variability of the primordial sun	.1
level of turbulence in the sun's primordial planetary disk	.1
proximity of long-lasting gamma ray bursts	.01
Earth formation date relative to the formation date for the solar system nebula	.02
silicon abundance in planetary system's primordial nebula	.01
intensity of ultraviolet radiation arriving from the sun at the	

time and shortly after life's origin on Earth (before photosynthesis can establish a significant ozone shield)	.002
wavelength response pattern of ultraviolet radiation arriving from the sun at the time or shortly after life's origin on Earth	.02
gas density of the local interstellar medium	.05
degree of oxidation of the phosphorus compounds in the protoplanetary disk of the solar nebula	.05
mass of the disk of dust, asteroids, and comets for the primordial planetary system	.01
degree to which the solar wind penetrates Earth's magnetosphere	.03
outer radius of the "dead zone," the low-viscosity, very-low-ionization zone for the primordial planetary disk	.01
cooling efficiency of the protoplanetary disk	.1
outer protoplanetary disk lifetime	.005
solid to gas ratio in the outer protoplanetary disk	.01
level of large scale turbulence in the protoplanetary disk	.02
average magnetic energy density in the quiet solar photosphere	.02
number density of spicules on the solar surface	.05
proximity of the primordial solar system nebula to the remnants of eruptions of novae	.05
number density of accreted intergalactic clouds in the vicinity of the emerging solar system nebula	.3
average mass of accreted intergalactic clouds in the vicinity of the emerging solar system nebula	.3
number density of accreted intergalactic clouds in the vicinity of the solar system during its life history	.1
average mass of accreted intergalactic clouds in the vicinity of the solar system during its life history	.1
number of supernova remnants in the vicinity of the life-support planet	.05
variation in the number of supernova remnants in the vicinity of the life support planet	.2
number of extrasolar planets and planetesimals captured from the outer planetary disks of near-passing stars	.1
proximity of the emerging solar system nebula to either a white dwarf or a neutron star that is accreting hydrogen gas or to the stellar winds blowing out from a neutron star or a collapsar disk	.002
closest proximity of the solar system to a black hole during the history of life	.5
quantity of warm dust in the interplanetary medium	.5
level of coronal mass ejections from the solar surface	.05
birthrate of massive stars in the solar neighborhood	.02
variation in birthrate of massive stars in the solar neighborhood	.1
peak-to-peak amplitude in the solar magnetic cycle	.01
inward migration of icy meter-sized rubble from the outer part of the protoplanetary disk	.001
density of stars in the sun's birthing star cluster	.01
carbon abundance in the protoplanetary disk of the potential life support planetary system	.001
planet formation time scale in the protoplanetary disk	.03

ratio of average surface magnetic field strength to the expansion factor of open magnetic flux tubes on the sun	.1
proximity of the emerging solar system nebula to very low mass red giant and asymptotic giant branch stars	.01
misalignment angle between the magnetic and rotational axes of the star during the planet formation era	.1
magnetization of the protoplanetary disk	.1
level of mixing of the elements and chemicals in the protoplanetary disk	.02
level of radial differential rotation during the sun's youth	.1
level of enhanced mixing in the interiors of low-mass red giant stars that were in the vicinity of the solar system's protoplanetary disk	.1
level of mixing in the early protoplanetary disk of the solar nebula	.05

Probability for occurrence of all 140 parameters  $\approx 6 \times 10^{-214}$   
 dependency factors estimate  $\approx 10^{95}$   
 longevity requirements estimate  $\approx 10^{-11}$

Probability for occurrence of all 140 parameters  $\approx 6 \times 10^{-130}$   
 Maximum possible number of stars in observable universe  $\approx 5 \times 10^{22}$

Thus, less than 1 chance in  $10^{108}$  exists that even one such star would occur anywhere in the universe without invoking divine miracles.

## D. Planetary System

Parameter	Probability that feature will fall in the required range for advanced physical life
absorption rate of planets and planetismals by parent star	.1
ratio of $^{40}\text{K}$ , $^{235,238}\text{U}$ , $^{232}\text{Th}$ to iron in star-planetary system	.001
galactic tidal forces on planetary system	.1
structure of comet cloud surrounding planetary system	.03
polycyclic aromatic hydrocarbon abundance in solar nebula	.01
density of interstellar and interplanetary dust particles in vicinity of life-support planet	.1
silicate dust annealing by nebular shocks	.02
asteroidal & cometary collision rate	.05
change in asteroidal & cometary collision rates	.1
rate of change in asteroidal & cometary collision rates	.1
mass of planet colliding with primordial Earth	.001
timing of planet colliding with primordial Earth	.02
location of planet's collision with primordial Earth	.02
biomass to comet infall ratio	.01
regularity of cometary infall	.1
formation of large terrestrial planet in the presence of two or more gas giant planets	.01
total mass of Oort Cloud objects	.1
mass distribution of Oort Cloud objects	.1
proximity of supernovae and hypernovae throughout history of planet and planetary system	.002
amount of photoevaporation during planetary formation from parent star and other nearby stars	.1
delivery rate of volatiles to planet from asteroid-comet belts during epoch of planet formation	.05
injection efficiency of shock wave material from nearby supernovae into collapsing molecular cloud that forms star and planetary system	.01
number and sizes of planets and planetesimals consumed by star	.3
viscosity gradient in protoplanetary disk	.1
frequency of late impacts by large asteroids and comets	.05
avoidance of apsidal phase locking in the orbits of planets in the planetary system	.03
average circumstellar medium density for white dwarf red giant pairs in the vicinity of the potential life support planet's protoplanetary disk	.1
quantity of volatiles on and in Earth-sized planet in the habitable zone	.0001
Kozai oscillation level in planetary system	.7
efficiency of stellar mass loss during final stages of stellar burning for old stars in vicinity of potential life support	.7

planet	.1
density of extragalactic intruder stars in solar neighborhood	.2
density of dust-exporting stars in solar neighborhood	.2
proximity of superbubbles to planetary system during life epoch of life-support planet	.02
proximity of strong ultraviolet emitting stars to planetary system during life epoch of life-support planet	.02
quantity and proximity of galactic gamma-ray burst events relative to time window for intelligent life	.1
infall of buckminsterfullerenes from interplanetary and interstellar space upon surface of planet	.3
flux of extrasolar dust into atmosphere	.5
inclination of the planes of the planetary system's asteroid belts	.1
variations in the inclinations of the planes of the planetary system's asteroid belts	.3
rate at which protoplanetary disk photoevaporates	.05
angle of planet's collision with primordial Earth	.05
velocity of planet's collision with primordial Earth	.01
depth of terrestrial water at point of planet's collision with primordial Earth	.02
number of gas giant planets in planetary system	.1
position & mass of Jupiter relative to Earth	.002
position & mass of Saturn relative to Earth	.01
position & mass of Uranus relative to Earth	.01
position & mass of Neptune relative to Earth	.01
ratio Saturn to Jupiter mass	.01
ratio of Uranus to Jupiter mass	.05
ratio of Neptune to Jupiter mass	.05
eccentricity and inclination of Jupiter's orbit	.05
eccentricity and inclination of Saturn's orbit	.05
eccentricity and inclination of Uranus's orbit	.1
eccentricity and inclination of Neptune's orbit	.1
major planet orbital variations and instabilities	.001
inward drift and rate of inward drift in major planet orbital distances during planetary system's formation history	.01
distance of gas giant planets from zones of mean motion resonances	.001
amount of outward migration by Jupiter during early solar system history	.01
amount of outward migration by Saturn during early solar system history	.01
amount of outward migration by Uranus during early solar system history	.1
amount of outward migration by Neptune during early solar system history	.1
initial mass of Kuiper Belt asteroids and comets	.1
initial mass distribution of Kuiper Belt asteroids and comets	.2
initial average orbital distance of Kuiper Belt asteroids and comets	.1

reduction of Kuiper Belt mass during planetary system's early history	.05
outward displacement of average orbital distance of Kuiper Belt asteroids and comets	.1
number of terrestrial planets in planetary system	.1
position and mass of other terrestrial planets in planetary system relative to Earth	.01
inclination and eccentricity of other terrestrial planets in planetary system	.01
distance of other terrestrial planets from zones of mean motion resonances	.01
planetary formation site within the circumstellar disk	.01
type, degree, and duration of interaction between the protoplanet and the circumstellar disk	.01
amount of migration from initial formation site for potential life support planet	.01
long term water loss from planet due to photodissociation	.01
average inclination of inner asteroid belt objects after the accretion era	.1
average inclination Kuiper Belt objects after the accretion era	.1
pebble density in solar nebula's protoplanetary disk	.005
intensity of far ultraviolet radiation from nearby stars when the circumsolar disk was condensing into planets	.001
phosphorus abundance in solar nebula	.03
timing of the 1:2 resonance event for Jupiter and Saturn	.005
mass of moon orbiting life support planet	.001
proximity of cold dark gas-dust clouds to life-support planet	.05
masses of nearest cold dark gas-dust clouds to life support planet	.05
timing of late heavy bombardment	.02
intensity of the late heavy bombardment	.02
chemical composition of the late heavy bombarders	.1
number of gamma ray burst events in the galaxy during life history on the life support planet	.1
proximity of gamma ray burst events to the life-support planet during the planet's life history	.1
velocity of planet colliding with primordial Earth relative to Earth	.002
collision angle relative to Earth of planet colliding with primordial Earth	.05
photo erosion by nearby giant stars during planetary formation phase	.005
surface density of the protoplanetary disk	.01
ratio of mass in the form of debris relative to mass in the form of planetesimals for the protoplanetary disk	.1
width of the primordial Kuiper Belt	.1
average mass of the primordial Kuiper Belt objects	.1
initial orbital distance of Jupiter	.01
initial orbital distance of Saturn	.02
initial orbital distance of Uranus	.04

initial orbital distance of Neptune	.05
timing of solar system's last crossing of a spiral arm	.02
ratio of asteroids to comets for the late heavy bombardment of Earth	.03
rate at which the sun loses masses during its first 1.0 to 1.5 billion years	.1
timing of potential life-support planet's birth relative to spiral substructure formation	.1
level of turbulence in the sun's primordial planetary disk	.1
frequency of long-lasting gamma ray bursts	.1
proximity of long-lasting gamma ray bursts	.01
impact energy of moon-forming collidor event	.0001
silicon abundance in planetary system's primordial nebula	.01
gas density of the local interstellar medium	.05
degree of oxidation of the phosphorus compounds in the protoplanetary disk of the solar nebula	.05
mass of the disk of dust, asteroids, and comets for the primordial planetary system	.01
inward migration of pebble-sized and smaller icy rubble from the outer primordial planetary disk	.01
ratio of iron to chondritic meteorites at the time and place of Earth's birth	.01
quantity of phosphorus mononitride and carbon monophosphide in the gas-dust cloud from which the solar system formed	.03
outer radius of the "dead zone," the low-viscosity, very-low-ionization zone for the primordial planetary disk	.01
cooling efficiency of the protoplanetary disk	.1
outer protoplanetary disk lifetime	.005
solid to gas ratio in the outer protoplanetary disk	.01
level of large scale turbulence in the protoplanetary disk	.02
proximity of the primordial solar system nebula to the remnants of eruptions of novae	.05
number density of accreted intergalactic clouds in the vicinity of the solar system during its life history	.1
average mass of accreted intergalactic clouds in the vicinity of the solar system during its life history	.1
number of supernova remnants in the vicinity of the life-support planet	.05
variation in the number of supernova remnants in the vicinity of the life support planet	.2
quantity of warm dust in the interplanetary medium	.5
inward migration of icy meter-sized rubble from the outer part of the protoplanetary disk	.001
carbon abundance in the protoplanetary disk of the potential life support planetary system	.001
planet formation time scale in the protoplanetary disk	.03
migration speed of Jupiter early in its history	.01
migration speed of Saturn early in its history	.02
migration speed of Uranus early in its history	.05
migration speed of Neptune early in its history	.05
magnetization of the protoplanetary disk	.1

level of mixing of the elements and chemicals in the protoplanetary disk	.02
level of enhanced mixing in the interiors of low-mass red giant stars that were in the vicinity of the solar system's protoplanetary disk	.1
timing of the movement of the main asteroid belt from its place of birth (much closer to the sun) to its present location (between Mars and Jupiter)	.1

Probability for occurrence of all 137 parameters  $\approx 9 \times 10^{-220}$   
 dependency factors estimate  $\approx 10^{96}$   
 longevity and timing requirements estimate  $\approx 10^{-8}$

Probability for occurrence of all 137 parameters  $\approx 9 \times 10^{-132}$   
 Maximum possible number of planetary systems in the observable universe  $\approx 4 \times 10^{20}$

Thus, less than 1 chance in  $10^{112}$  exists that even one such planetary system would occur anywhere in the universe without invoking divine miracles.

## E. Planet

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<b>Parameter</b>	<b>Probability that feature will fall in the required range for advanced physical life</b>
planetary distance from star	.001
inclination of planetary orbit	.1
axis tilt of planet	.1
rate of change of axial tilt	.01
period and size of axis tilt variation	.1
planetary rotation period	.01
rate of change in planetary rotation period	.05
planetary revolution period	.2
planetary orbital eccentricity	.05
rate of change of planetary orbital eccentricity	.1
rate of change of planetary inclination	.2
period and size of planetary eccentricity variation	.01
period and size of planetary inclination variation	.02
precession in planet's rotation	.3
rate of change in planet's precession	.3
number of moons	.1
surface gravity (escape velocity)	.001
tidal force from sun	.1
tidal force from moon	.1
magnetic field of planet	.01
rate of change & character of change in magnetic field	.1
albedo (planet reflectivity)	.05
density of planet	.01
reducing strength of planet's primordial mantle	.3
thickness of crust	.01
timing of birth of continent formation	.02
mass of planet colliding with primordial Earth	.001
timing of planet colliding with primordial Earth	.02
location of planet's collision with primordial Earth	.02
atmospheric transparency	.01
atmospheric pressure	.002
atmospheric viscosity	.05
atmospheric temperature gradient	.005
carbon dioxide quantity in atmosphere	.0001
total quantity of water vapor in the atmosphere	.0001
percentage of the atmosphere comprised of water vapor	.01
methane quantity in the atmosphere	.001
rates of change in carbon dioxide levels in atmosphere throughout the planet's history	.00001
rates of change in water vapor levels in atmosphere throughout the planet's history	.00001
rates of change in methane level in atmosphere throughout the planet's history	.0001

oxygen quantity in atmosphere	.000001
rate of change in oxygen level in atmosphere throughout the planet's history	.0000001
nitrogen quantity in atmosphere	.001
carbon monoxide quantity in atmosphere	.01
chlorine quantity in atmosphere	.01
cobalt quantity in crust and/or soil	.1
arsenic quantity in crust and/or soil	.05
copper quantity in crust and/or soil	.1
boron quantity in crust and/or soil	.1
cadmium quantity in crust and/or soil	.1
calcium quantity in crust and/or soil	.4
fluorine quantity in crust and/or soil	.1
iodine quantity in crust and/or soil	.05
magnesium in crust and/or soil	.2
manganese quantity in crust and/or soil	.1
nickel quantity in crust and/or soil	.1
phosphorus quantity in crust and/or soil	.01
potassium quantity in crust and/or soil	.4
tin quantity in crust and/or soil	.1
zinc quantity in crust and/or soil	.1
molybdenum quantity in crust and/or soil	.05
vanadium quantity in crust and/or soil	.1
chromium quantity in crust and/or soil	.1
selenium quantity in crust and/or soil	.1
tropospheric ozone quantity	.01
stratospheric ozone quantity	.01
mesospheric ozone quantity	.01
oxygen to nitrogen ratio in atmosphere	.01
quantity of greenhouse gases in atmosphere	.01
rate of change in greenhouse gases in atmosphere	.01
poleward heat transport in atmosphere by mid-latitude storms	.2
quantity of sea salt aerosols in troposphere	.03
phosphorus and iron absorption by banded iron formations	.01
ratio of electrically conducting inner core radius to radius of the adjacent turbulent fluid shell	.2
ratio of core to shell (see above) magnetic diffusivity	.2
magnetic Reynold's number of the shell (see above)	.2
elasticity of iron in the inner core	.2
electromagnetic Maxwell shear stresses in the inner core	.2
core precession frequency for planet	.1
rate of interior heat loss for planet	.1
quantity of sulfur in the planet's core	.1
quantity of silicon in the planet's core	.1
quantity of water at subduction zones in the crust	.005
quantity of high pressure ice in subducting crustal slabs	.1
hydration rate of subducted minerals	.1
water absorption capacity of planet's lower mantle	.1
tectonic activity	.005
rate of decline in tectonic activity	.05
volcanic activity	.02

rate of decline in volcanic activity	.1
location of volcanic eruptions	.05
viscosity at Earth core boundaries	.01
viscosity of lithosphere	.2
thickness of mid-mantle boundary	.1
rate of sedimentary loading at crustal subduction zones	.05
biomass to comet infall ratio	.01
regularity of cometary infall	.1
air turbulence in troposphere	.05
quantity of sulfate aerosols in troposphere	.05
hydrothermal alteration of ancient oceanic basalts	.01
location of dislocation creep relative to diffusion creep in and near the crust-mantle boundary (determines mantle convection dynamics)	.1
size of oxygen sinks in the planet's crust	.05
size of oxygen sinks in the planet's mantle	.05
mantle plume production	.1
degree to which the atmospheric composition of the planet departs from thermodynamic equilibrium	.01
delivery rate of volatiles to planet from asteroid-comet belts during epoch of planet formation	.05
Q-value (rigidity) of planet during its early history	.2
variation in Q-value of planet during its early history	.3
frequency of late impacts by large asteroids and comets	.05
size of the carbon sink in the deep mantle of the planet	.05
ratio of dual water molecules, (H <sub>2</sub> O) <sub>2</sub> , to single water molecules, H <sub>2</sub> O, in the troposphere	.03
quantity of volatiles on and in Earth-sized planet in the habitable zone	.0001
triggering of El Nino events by explosive volcanic eruptions	.1
efficiency of flows of silicate melt, hypersaline hydrothermal fluids, and hydrothermal vapors in the upper crust	.1
quantity and proximity of galactic gamma-ray burst events relative to time window for intelligent life	.1
infall of buckminsterfullerenes from interplanetary and interstellar space upon surface of planet	.3
water absorption by planet's mantle	.01
density and thickness of atmosphere	.001
flux of extrasolar dust into atmosphere	.5
oxygen quantity in inner core	.01
oxygen quantity in outer core	.01
lifetimes of methane in different atmospheric layers	.01
ratio of moon's mass to planet's mass	.001
surface air pressure of Earth's primordial atmosphere	.01
chemical composition of Earth's primordial atmosphere	.05
chemical composition of planet colliding with primordial Earth	.01
angle of planet's collision with primordial Earth	.05
velocity of planet's collision with primordial Earth	.01
depth of terrestrial water at point of planet's collision with primordial Earth	.02
size of the planet's core relative to planet size	.01

position & mass of Jupiter relative to Earth	.002
position & mass of Saturn relative to Earth	.01
position & mass of Uranus relative to Earth	.01
position & mass of Neptune relative to Earth	.01
position and mass of other terrestrial planets in planetary system relative to Earth	.01
amount of migration from initial formation site for potential life support planet	.01
level of dislocation creep of the lower mantle's silicate perovskite	.1
pressure at planet's core-mantle boundary	.03
temperature at planet's core-mantle boundary	.1
quantity of iron in planet's core	.001
long term water loss from planet due to photodissociation	.01
upper mantle viscosity	.05
lower mantle viscosity	.1
mantle temperature	.1
relative abundance of perovskite in lower mantle	.1
relative abundance of mangesiowüstite in lower mantle	.1
radiative conductivity of lower mantle	.05
average degree of plate subduction at plate boundaries	.05
average longevity of plate subduction at plate boundaries	.05
magnitude of air movement at the boundaries of water vapor clouds in planet's atmosphere	.01
time window between the production of cisterns in the planet's crust that can effectively collect and store petroleum and natural gas and the appearance of intelligent life	.05
average size of hurricanes	.1
average wind velocity of hurricanes	.1
average lifespan of hurricanes	.1
frequency of hurricanes	.1
location of hurricanes	.1
magnitude of chemical exchange occurring at the liquid core-deep mantle boundary of planet	.1
amount of methane generated in upper mantle of planet	.03
rate at which the planet's biosphere is oxygenated	.001
level of biogenic mixing of seafloor sediments	.0001
planet's silicate abundance	.1
mass of moon orbiting life support planet	.001
timing of late heavy bombardment	.02
intensity of the late heavy bombardment	.02
chemical composition of the late heavy bombarders	.1
depth of Earth's primordial ocean	.01
rate of quartz re-precipitation on Earth	.1
availability of fossil fuels to humanity	.1
upper mantle seismic anisotropy	.1
lower mantle seismic anisotropy	.1
average albedo of Earth's surface life	.001
number of gamma ray burst events in the galaxy during life history on the life support planet	.1
proximity of gamma ray burst events to the life-support planet during the planet's life history	.1

velocity of planet colliding with primordial Earth relative to Earth	.002
collision angle relative to Earth of planet colliding with primordial Earth	.05
quantity of terrestrial lightning	.01
type of terrestrial lightning	.05
variation in quantity and type of terrestrial lightning	.1
timing of solar system's last crossing of a spiral arm	.02
date for the beginning of deposition of petroleum	.05
date for the beginning of deposition of coal	.05
amount of iron-60 injected into Earth's primordial core from a nearby type II supernova eruption	.03
thickness of iron-rich silicate layer between the lower mantle and outer liquid core	.1
diffusivity of iron-rich silicate layer between the lower mantle and outer liquid core	.1
magnetism of iron-rich silicate layer between the lower mantle and outer liquid core	.1
elastic anisotropy of iron-rich silicate layer between the lower mantle and outer liquid core	.1
timing of humanity's arrival relative to a magnetic reversal event	.03
interval between magnetic reversals during epoch of human occupation	.002
Ekman number (relative importance of viscosity to rotation rate) for Earth's interior	.03
date of onset of efficient subduction tectonic activity	.02
quantity of uranium in the inner core	.01
quantity of uranium in the outer core	.01
quantity of uranium in the bottom mantle	.01
quantity of uranium in middle and upper mantle layers	.01
quantity of uranium in the crust	.01
quantity of thorium in the inner core	.01
quantity of thorium in the outer core	.01
quantity of thorium in the bottom mantle	.01
quantity of thorium in the middle and upper mantle layers	.01
quantity of thorium in the crust	.01
quantity of potassium-40 in the bottom mantle	.01
quantity of potassium-40 in the middle and upper mantle layers	.01
timing of the rise in oxygen content in the atmosphere relative to mass extinction/speciation events	.001
ratio of asteroids to comets for the late heavy bombardment of Earth	.03
level of rock melting during tectonic fault movements	.01
timing of continental growth spurts	.001
mass of the potential life support planet	.002
timing of potential life-support planet's birth relative to spiral substructure formation	.1
frequency of long-lasting gamma ray bursts	.1
proximity of long-lasting gamma ray bursts	.01
impact energy of moon-forming collidor event	.0001

Earth formation date relative to the formation date for the solar system nebula	.02
flux of interplanetary dust into atmosphere	.7
density of particulates in the atmosphere	.01
frequency of giant volcanic eruptions	.01
timing of giant volcanic eruptions relative to time window for advanced life	.1
rate at which abiotic processes deplete nitrogen from the atmosphere by converting that nitrogen into ocean-deposited nitrates	.2
production and release of ammonium sulfate aerosols into the atmosphere	.1
timing of the first great oxygenation event	.001
timing of the second great oxygenation event	.002
timing of the third great oxygenation event	.002
hydrogen escape from the atmosphere to outer space	.01
variation in the rate of hydrogen escape from the atmosphere to outer space	.1
magnitude of the change in eccentricity of Earth's orbit in the 2.37 million year eccentricity cycle	.03
magnitude of the change in obliquity of Earth's orbit in the 1.2 million year obliquity cycle	.03
intensity of ultraviolet radiation arriving from the sun at the time and shortly after life's origin on Earth (before photosynthesis can establish a significant ozone shield)	.002
wavelength response pattern of ultraviolet radiation arriving from the sun at the time or shortly after life's origin on Earth	.02
degree to which the solar wind penetrates Earth's magnetosphere	.03
magnitude of tidal Coulomb stresses (stress imparted by tides on tectonic fault zones)	.1
ratio of viscous to rotational forces in the planet's liquid core	.01
planet's oxygenation time (time for atmospheric oxygen to reach a level capable of supporting advanced life)	.00001
ratio of iron to chondritic meteorites at the time and place of Earth's birth	.01
saltiness of the planet's surface crustal layers	.1
thermal pressure of the planet's ionosphere	.01
stability of the thermal pressure of the planet's atmosphere	.001
number of tectonic plates making up the surface crust	.05
number of supernova remnants in the vicinity of the life-support planet	.05
variation in the number of supernova remnants in the vicinity of the life support planet	.2
quantity of hydroxyl (OH) in the planet's troposphere	.01
variation in the quantity of hydroxyl in the planet's troposphere	.1
quantity of hydroxyl (OH) in the planet's stratosphere	.01
variation in the quantity of hydroxyl in the planet's stratosphere	.1
frequency of mega-volcanic eruptions on the life support planet	.01
timing of the introduction of the equivalent of a human species relative to the last mega-volcanic eruption	.05
average depth of oxygenated marine sediments	.001

variation in average depth of oxygenated marine sediments	.05
date for onset of crust formation for the planet	.1
date for onset of sediment recycling for the planet	.1
average pore pressure at subduction zones	.01
average rate of migration of aqueous fluids through the planet's upper crust	.002
radiative thermal conductivity level of the lower mantle	.01
abundance of olivine in the upper mantle	.1
trace element abundance in atmospheric dust	.05
rate of atmospheric dust deposition to the surfaces of oceans	.05
variation in the level of dust supply to the surfaces of oceans	.2
level of chemical heterogeneities throughout the lower mantle	.1
quantity of sulfuric acid in the troposphere	.01
quantity of ammonia in the troposphere	.1
quantity of iodine oxide in the troposphere	.1
level of atmospheric oxidation of aromatics	.1
rate at which the planet's inner core rotates faster than the mantle and the crust	.1
quantity of carbon dioxide extracted from the mantle by melting beneath mid-ocean ridges	.1
quantity of carbon dioxide extracted from the mantle by volcanic eruptions	.2
average size of aerosol particles in the troposphere	.1
date for the beginning of significant plate tectonic activity	.01
rate of decline in seawater temperature over the past four billion years	.01
quantity of hydrated minerals in the mantle	.001
quantity of hydrogen peroxide produced in the atmosphere	.5

Probability for occurrence of all 268 parameters  $\approx 4 \times 10^{-444}$   
dependency factors estimate  $\approx 10^{169}$   
longevity and timing requirements estimate  $\approx 10^{-27}$

Probability for occurrence of all 268 parameters  $\approx 4 \times 10^{-302}$   
Maximum possible number of planets in the observable universe  $\approx 4 \times 10^{21}$

Thus, less than 1 chance in  $10^{281}$  exists that even one such planet would occur anywhere in the universe without invoking divine miracles.

## F. Moon

Parameter	Probability that feature will fall in the required range for advanced physical life
number of moons	.05
distance of moon from star	.001
ratio of moon's mass to planet's mass	.001
eccentricity of moon's orbit	.2
inclination of moon's orbit	.2
tidal force exerted by moon on the planet	.1
mass of planet colliding with primordial Earth	.001
timing of planet colliding with primordial Earth	.02
location of planet's collision with primordial Earth	.02
velocity of planet's collision with primordial Earth	.01
depth of terrestrial water at point of planet's collision with primordial Earth	.001
mass of moon orbiting life support planet	.01
timing of late heavy bombardment	.02
intensity of the late heavy bombardment	.02
chemical composition of the late heavy bombarders	.1
average depth of Earth's primordial ocean	.01
surface air pressure of Earth's primordial atmosphere	.01
chemical composition of Earth's primordial atmosphere	.05
chemical composition of planet colliding with primordial Earth	.01
velocity of planet colliding with primordial Earth relative to Earth	.002
collision angle relative to Earth of planet colliding with primordial Earth	.05
impact energy of moon-forming collidor event	.0001
magnitude of tidal Coulomb stresses (stress imparted by tides on tectonic fault zones)	.1
Q-value (rigidity) of moon during its early history	.1
rate at which moon spirals away from planet	.01
moon's distance from planet at the epoch of intelligent life	.001
moon's albedo	.1

Probability for occurrence of all 27 parameters  $\approx 2 \times 10^{-51}$   
 dependency factors estimate  $\approx 10^{13}$   
 longevity and timing requirements estimate  $\approx 10^{-1}$

Probability for occurrence of all 27 parameters  $\approx 10^{-39}$   
 Maximum possible number of moons in observable universe  $\approx 10^{23}$

Thus, less than 1 chance in  $10^{16}$  exists that even one such moon would occur anywhere in the universe without invoking divine miracles.

<b>Parameter</b>	<b>Probability that feature will fall in the required range for advanced physical life</b>
albedo (planet reflectivity)	.05
timing of birth of continent formation	.02
oceans-to-continent ratio	.05
rate of change in oceans to continent ratio	.1
global distribution of continents	.01
frequency, timing, & extent of ice ages	.1
frequency, timing, & extent of global snowball events	.1
average rainfall precipitation	.0001
variation and timing of average rainfall precipitation	.001
cobalt quantity in crust and/or soil	.1
arsenic quantity in crust and/or soil	.05
copper quantity in crust and/or soil	.1
boron quantity in crust and/or soil	.1
cadmium quantity in crust and/or soil	.1
calcium quantity in crust and/or soil	.4
fluorine quantity in crust and/or soil	.1
iodine quantity in crust and/or soil	.05
magnesium in crust and/or soil	.2
manganese quantity in crust and/or soil	.1
nickel quantity in crust and/or soil	.1
phosphorus quantity in crust and/or soil	.01
potassium quantity in crust and/or soil	.4
tin quantity in crust and/or soil	.1
zinc quantity in crust and/or soil	.1
molybdenum quantity in crust and/or soil	.05
vanadium quantity in crust and/or soil	.1
chromium quantity in crust and/or soil	.1
selenium quantity in crust and/or soil	.1
iron quantity in oceans	.01
poleward heat transport in atmosphere by mid-latitude storms	.2
soil mineralization	.01
phosphorus and iron absorption by banded iron formations	.01
quantity of water at subduction zones in the crust	.005
quantity of high pressure ice in subducting crustal slabs	.1
hydration rate of subducted minerals	.1
location of volcanic eruptions	.05
continental relief	.1
rate of sedimentary loading at crustal subduction zones	.05
hydrothermal alteration of ancient oceanic basalts	.01
triggering of El Nino events by explosive volcanic eruptions	.1
efficiency of flows of silicate melt, hypersaline hydrothermal fluids, and hydrothermal vapors in the upper crust	.1
efficiency of ocean pumps that return nutrients to ocean surfaces	.1

sulfur and sulfate content of oceans	.2
orientation of continents relative to prevailing winds	.2
quantity of silicic acid in the oceans	.1
quantity of mountains on land	.2
average height of mountains on land	.2
degree of continental land mass barrier to oceans along planet's rotation axis	.04
oxygen quantity in oceans	.01
nitrogen quantity in oceans	.03
magnitude of non-volcanically triggered El Nino and El Nina events	.2
rate of non-volcanically triggered El Nino and El Nina events	.2
average degree of plate subduction at plate boundaries	.05
average longevity of plate subduction at plate boundaries	.05
magnitude of air movement at the boundaries of water vapor clouds in planet's atmosphere	.01
time window between the production of cisterns in the planet's crust that can effectively collect and store petroleum and natural gas and the appearance of intelligent life	.05
coupling strength between local soil moisture and precipitation	.1
mean soil depth	.05
mean percentage of clays in soil	.3
mean percentage of sands in soil	.3
average size of hurricanes	.1
average wind velocity of hurricanes	.1
average lifespan of hurricanes	.1
frequency of hurricanes	.1
location of hurricanes	.1
amount of methane generated in upper mantle of planet	.03
rate at which the planet's biosphere is oxygenated	.001
salinity of the deep ocean	.1
convection in the deep ocean	.1
ventilation of oxygen and carbon dioxide in the deep ocean	.1
level and frequency of ocean microseisms	.1
average slope of the coastline land masses	.1
depth of Earth's primordial ocean	.01
rate of quartz re-precipitation on Earth	.1
quantity of terrestrial lightning	.01
type of terrestrial lightning	.05
variation in quantity and type of terrestrial lightning	.1
timing of humanity's arrival relative to a magnetic reversal event	.03
interval between magnetic reversals during epoch of human occupation	.002
quantity of soil sulfur	.01
level of oxidizing activity in the soil	.02
variation in level of oxidizing activity in the soil	.2
level of water soluble heavy metals in soils	.001
timing of the rise in oxygen content in the atmosphere relative to mass extinction/speciation events	.001

quantity of soluble zinc in the oceans	.05
quantity of soluble silicon and silica in the oceans	.05
quantity of phosphorous and phosphates in the oceans	.01
availability of light to upper layers of the oceans	.1
quantity of dissolved calcium in lakes and rivers	.1
quantity of suspended calcium in lakes and rivers	.1
level of rock melting during tectonic fault movements	.01
timing of continental growth spurts	.001
quantity of clay production on continental land masses	.001
timing of advent of clay production on continental land masses	.003
date for opening of the Drake Passage (between South America and Antarctica)	.01
frequency of giant volcanic eruptions	.01
timing of giant volcanic eruptions relative to time window for advanced life	.1
rate at which abiotic processes deplete nitrogen from the atmosphere by converting that nitrogen into ocean- deposited nitrates	.2
production and release of ammonium sulfate aerosols into the atmosphere	.1
timing of the first great oxygenation event	.001
timing of the second great oxygenation event	.002
timing of the third great oxygenation event	.002
intensity of ultraviolet radiation arriving from the sun at the time and shortly after life's origin on Earth (before photosynthesis can establish a significant ozone shield)	.002
wavelength response pattern of ultraviolet radiation arriving from the sun at the time or shortly after life's origin on Earth	.02
frequency of Heinrich events (liberation of iceberg armadas)	.1
intensity of Heinrich events	.1
timing of Heinrich events relative to global human civilization	.1
amount of methane stored in ocean clathrates	.1
planet's oxygenation time (time for atmospheric oxygen to reach a level capable of supporting advanced life)	.00001
saltiness of the planet's surface crustal layers	.1
number of tectonic plates making up the surface crust	.05
frequency of mega-volcanic eruptions on the life support planet	.01
timing of the introduction of the equivalent of a human species relative to the last mega-volcanic eruption	.05
high latitude precipitation	.01
duration of El Nino events	.1
average depth of oxygenated marine sediments	.001
variation in average depth of oxygenated marine sediments	.05
habitat space for land mammals	.01
date for onset of crust formation for the planet	.1
date for onset of sediment recycling for the planet	.1
average pore pressure at subduction zones	.01
average rate of migration of aqueous fluids through the planet's upper crust	.002
rate of atmospheric dust deposition to the surfaces of oceans	.05
variation in the level of dust supply to the surfaces of oceans	.2

level of deep ocean convection	.05
variation in level of deep ocean convection	.2
level of atmospheric oxidation of aromatics	.1
quantity and extent of wetland ecosystems	.01
quantity of carbon dioxide extracted from the mantle by melting beneath mid-ocean ridges	.1
quantity of carbon dioxide extracted from the mantle by volcanic eruptions	.2
quantity of soil nitrogen	.05
variation in quantity of soil nitrogen	.2
surface air pressure of Earth's primordial atmosphere	.01
chemical composition of Earth's primordial atmosphere	.05
chemical composition of planet colliding with primordial Earth	.01
date for the beginning of significant plate tectonic activity	.01
rate of decline in seawater temperature over the past four billion years	.01

Probability for occurrence of all 137 parameters  $\approx 4 \times 10^{-201}$   
 dependency factors estimate  $\approx 10^{88}$   
 longevity and timing requirements estimate  $\approx 10^{-14}$

Probability for occurrence of all 137 parameters  $\approx 4 \times 10^{-127}$   
 Maximum possible number of planets in observable universe  $\approx 4 \times 10^{21}$

Thus, less than 1 chance in  $10^{106}$  exists that even one such planetary surface would occur anywhere in the universe without invoking divine miracles.

## H. Planet's Other Life (Ecosystem)

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Parameter	Probability that feature will fall in the required range for advanced physical life
rates of change in methane level in atmosphere throughout the planet's history	.0001
atmospheric transparency	.01
oxygen quantity in atmosphere	.000001
rate of change in oxygen level in atmosphere throughout the planet's history	.0000001
aerosol particle density emitted from forests	.05
tropospheric ozone quantity	.01
stratospheric ozone quantity	.01
mesospheric ozone quantity	.01
oxygen to nitrogen ratio in atmosphere	.01
quantity of greenhouse gases in atmosphere	.01
rate of change in greenhouse gases in atmosphere	.01
carbon dioxide quantity in atmosphere	.0001
total quantity of water vapor in the atmosphere	.0001
percentage of the atmosphere comprised of water vapor	.01
methane quantity in the atmosphere	.001
rates of change in carbon dioxide levels in atmosphere throughout the planet's history	.00001
rates of change in water vapor levels in atmosphere throughout the planet's history	.00001
quantity and extent of forest fires	.001
quantity and extent of grass fires	.01
quantity of anaerobic bacteria in the oceans	.001
quantity of aerobic bacteria in the oceans	.00001
quantity of anaerobic nitrogen-fixing bacteria in the early oceans	.0001
quantity, variety, and timing of sulfate-reducing bacteria	.0000001
quantity of geobacteraceae	.001
quantity of aerobic photoheterotrophic bacteria	.0000001
quantity of decomposer bacteria in soil	.001
quantity of mycorrhizal fungi in soil	.01
quantity of nitrifying microbes in soil	.001
quantity & timing of vascular plant introductions	.0001
quantity, timing, & placement of carbonate-producing animals	.00001
quantity, timing, & placement of methanogens	.00001
phosphorus and iron absorption by banded iron formations	.01
biomass to comet infall ratio	.01
quantity of actinide bioreducing bacteria	.001
quantity of phytoplankton	.00001
quantity of iodocarbon-emitting marine organisms	.001
minimization of chloromethane production by rotting plants	

and fungi that are exposed to the atmosphere (life's survival demands very efficient burial mechanisms and relatively low temperatures)	.01
methane emissions from living plants	.001
methane emissions from plant litter	.2
methane emissions from animals	.01
methane emissions from fossil fuel production	.01
rate of release of biogenic bromides into the atmosphere	.001
decomposition rate of biogenic bromides in the atmosphere	.01
quantity of trees	.00001
diversity of trees	.001
distribution of trees	.01
quantity of grasses	.0001
diversity of grasses	.001
distribution of grasses	.01
height of the tallest trees	.1
diversity of herbivore species	.0001
degree of feeding specialization by herbivore species	.01
diversity of plant species	.0001
diversity of carnivore species	.001
degree of feeding specialization by carnivore species	.01
diversity of plant parasite species	.0001
quantity of plant parasites	.001
diversity of animal parasite species	.0001
quantity of animal parasites	.001
degree of feeding specialization by parasite species	.01
quantity of large-celled nitrogen fixing cyanobacteria in the oceans	.001
quantity of small-celled nitrogen fixing cyanobacteria in the oceans	.001
quantity of nitrogen fixing bacterioplankton in the oceans	.001
time window between the peak of kerogen production and the appearance of intelligent life	.01
mean percentage of clays in soil	.3
average width of the light spectrum utilized by phytoplankton species throughout life's history on the planet	.001
level of biogenic mixing of seafloor sediments	.0001
diversity of soil-dwelling invertebrates	.001
cicada resource pulses in forest ecosystems	.01
production of organic aerosols in the atmosphere	.01
lifetimes of organic aerosols in the atmosphere	.01
quantity of chlorinated-toxins-consuming bacteria	.0001
quantity of sub-seafloor hypersaline anoxic bacteria	.0001
variation in quantity of sub-seafloor hypersaline anoxic bacteria	.05
rate of release of cellular particles (fur fiber, dandruff, pollen, spores, bacteria, etc.) into the atmosphere	.001
rate of release of protein and viral particles into the atmosphere	.001
rate of leaf litter deposition upon soils	.01
availability of fossil fuels to humanity	.1

average albedo of Earth's surface life	.001
date for the beginning of deposition of petroleum	.05
date for the beginning of deposition of coal	.05
quantity of arbuscular mycorrhizal fungi in continental soils	.00001
location of arbuscular mycorrhizal fungi in continental soils	.001
variation in quantity and location of arbuscular mycorrhizal fungi in continental soils	.01
quantity of plants using C <sub>3</sub> photosynthesis	.01
quantity of plants using C <sub>4</sub> photosynthesis	.01
variation in quantity of plants using C <sub>3</sub> photosynthesis	.1
variation in quantity of plants using C <sub>4</sub> photosynthesis	.1
timing of humanity's arrival relative to a magnetic reversal event	.03
interval between magnetic reversals during epoch of human occupation	.002
level of oxidizing activity in the soil	.02
variation in level of oxidizing activity in the soil	.2
level of nitrogen fixation by marine organisms	.0001
variation in level of nitrogen fixation by marine organisms	.01
level of water soluble heavy metals in soils	.001
quantity of methanotrophic symbionts in wetlands	.001
timing of the rise in oxygen content in the atmosphere relative to mass extinction/speciation events	.001
quantity of viruses in the oceans	.0001
diversity of viruses in the oceans	.001
variation in the quantity and diversity of viruses in the oceans	.01
quantity amomox bacteria (bacteria exploiting anaerobic ammonium oxidation reactions) in the oceans	.005
variation in the quantity of amomox bacteria	.1
quantity of phosphorous and phosphates in the oceans	.01
average cell size of marine phytoplankton	.02
amount of summer ground foliage in the arctic	.2
methane production and release to the atmosphere by plants	.1
variation in methane production and release to the atmosphere by plants	.2
quantity and diversity of life forms that enhance clay production	.00001
timing of the introduction of life forms that enhance clay production	.001
quantity of clay production on continental land masses	.001
timing of advent of clay production on continental land masses	.003
quantity of bacteriophages	.0001
diversity of bacteriophages	.0001
variation in the quantity and diversity of bacteriophages	.01
rate at which biological organisms convert nitrates in the ocean into free nitrogen that is subsequently released into the atmosphere	.0001
level of upward stirring of ocean water by krill	.001
variation in level of upward stirring of ocean water by krill	.05
timing of the first great oxygenation event	.001
timing of the second great oxygenation event	.002
timing of the third great oxygenation event	.002

amount of methane stored in ocean clathrates	.1
planet's oxygenation time (time for atmospheric oxygen to reach a level capable of supporting advanced life)	.00001
timing of the appearance of methanogenic bacteria relative to the timing of the appearance of photosynthetic bacteria	.0001
relative abundance of methanogenic life compared to photosynthetic life	.003
variation in the relative abundance of methanogenic life compared to photosynthetic life	.01
timing of the introduction of the equivalent of a human species relative to the last mega-volcanic eruption	.05
percentage of the planet's surface covered by forests	.001
variation in percentage of the planet's surface covered by forests	.05
average depth of oxygenated marine sediments	.001
variation in average depth of oxygenated marine sediments	.05
timing of the spread of fungal species on the continental land masses	.01
quantity and diversity of fungi on the continental land masses	.0001
quantity and diversity of oxygen-tolerant anaerobes	.001
variation in quantity and diversity of oxygen tolerant anaerobes	.1
quantity of volatile organic compounds released into the atmosphere by trees	.01
quantity of nitrogen-fixing cyanobacteria in corals	.001
rate at which dissolved organic matter cycles through the oceans	.01
rate of remineralization of particulate organic matter	.1
quantity of large-celled sulfur bacteria in the oceans	.00001
variation in quantity of large-celled sulfur bacteria in the oceans	.01
quantity of fallen leaf litter	.1
quantity and extent of wetland ecosystems	.01
quantity of endophytic methanotrophic bacteria in freshwater wetland ecosystems	.0001
quantity of marine methanotrophic archaea	.0001
variation in quantity of marine methanotrophic archaea	.01
diversity of prokaryote microorganisms	.0001
diversity of eukaryote microorganisms	.0001
level of synergistic interactions among bacterial species	.00001
variation in level of synergistic interactions among bacterial species	.01
quantity of phosphonate-mining bacteria in the oceans	.00001
variation in quantity of phosphonate-mining bacteria in the oceans	.01
quantity and diversity of siderophore-secreting bacteria in the oceans	.0001
variation in quantity and diversity of siderophore-secreting bacteria in the oceans	.01
quantity of soil nitrogen	.05
variation in quantity of nitrogen	.2
quantity of marine snow (dead cells, shreds of plankton, bits of faeces, and mineral grains) in the oceans	.01
quantity of Trichodesmium bacteria in the oceans	.0001
depth distribution of Trichodesmium bacteria in the oceans	.02
variation in quantity and distribution of Trichodesmium bacteria in the oceans	.01

Probability for occurrence of all 159 parameters  $\approx 10^{-442}$   
dependency factors estimate  $\approx 10^{65}$   
longevity and timing requirements estimate  $\approx 10^{-35}$

Probability for occurrence of all 159 parameters  $\approx 10^{-412}$   
Maximum possible number of planets in the observable universe  $\approx 4 \times 10^{21}$

Thus, less than 1 chance in  $10^{390}$  exists that even one planet containing the necessary kinds of life would occur anywhere in the universe without invoking divine miracles.

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